Sea ice, snow, and ice sheet observations

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obs4MIPs – CMIP6 Planning Meeting
30 April 2014

Ice Sheets

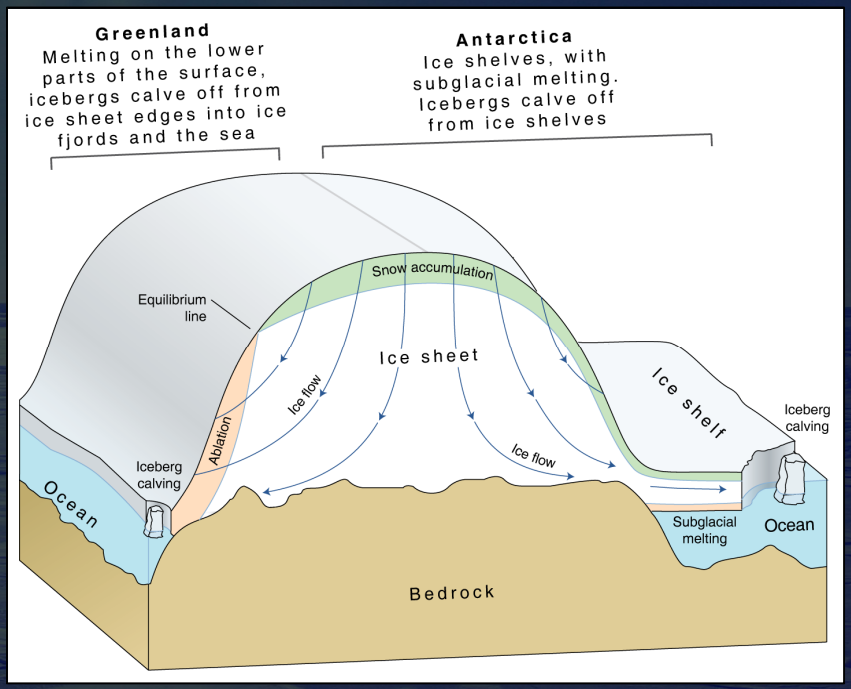
Key questions:

- Will CMIP6 models include ice sheet models?
- Which ice sheet models will be used?
- What value do ice sheet models bring to CMIP6?
- What ice sheet data will be relevant to CMIP6?

Ice Sheets

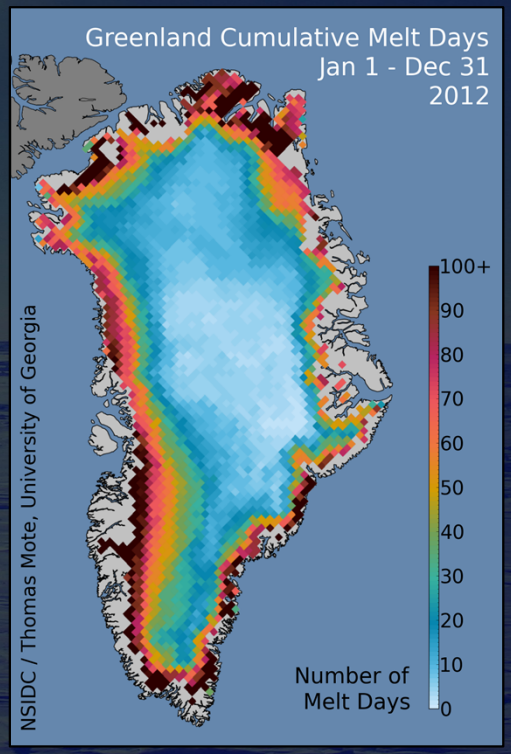
- GCM models do not well capture detailed ice sheet processes, especially dynamics
- Important parameters:
  - Ice sheet elevation
  - Glacier flow speeds
  - DEMs, bedrock topography
  - Grounding line
  - Calving front
  - Ocean temperatures (incl. sub-surface)
  - Atmospheric forcing (e.g., precipitation), surface albedo, fluxes

Ice shelf – ocean interactions



Ice Sheets

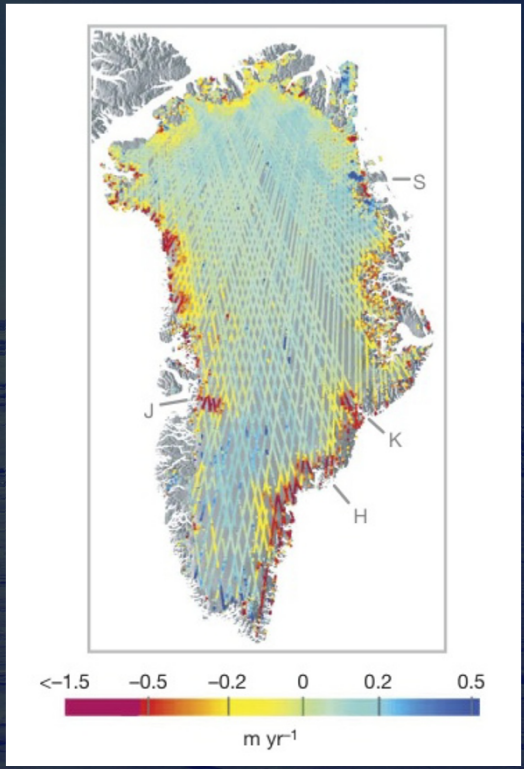
- Surface melt (microwave), 1979-present
  - T. Mote, Univ. Ga. (MEaSUREs)
  - M. Tedesco, City College New York
- Ice stream velocities from InSAR
  - NASA MEaSUREs data sets at NSIDC (E. Rignot, I. Joughin)
  - ESA CCI
  - Variable periods since mid-1990s



Greenland Melt map from T. Mote, Univ. Georgia (NSIDC Greenland Today website)

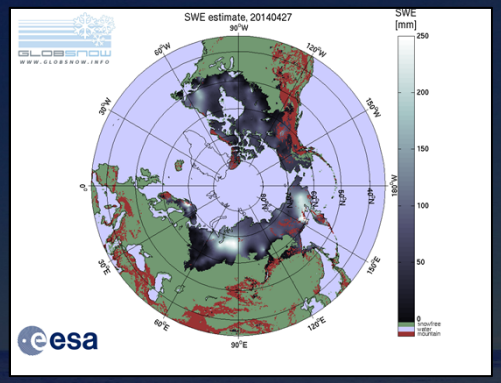
Ice Sheets

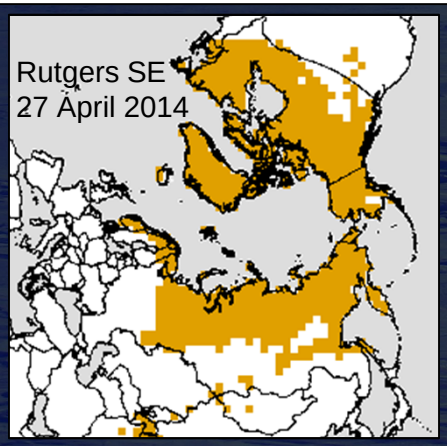
- Ice sheet elevation (2003-present)
  - NASA ICESat and IceBridge
  - ESA CCI
  - Earlier data from ERS-1/2 and aircraft
- Ice mass balance from NASA GRACE (2002-present)
- Grounding line and calving front
  - ESA CCI
  - NASA ICESat and IceBridge



Greenland elevation change, 2003-2007, from ICESat (Pritchard et al., 2009)

Snow extent, water equivalent



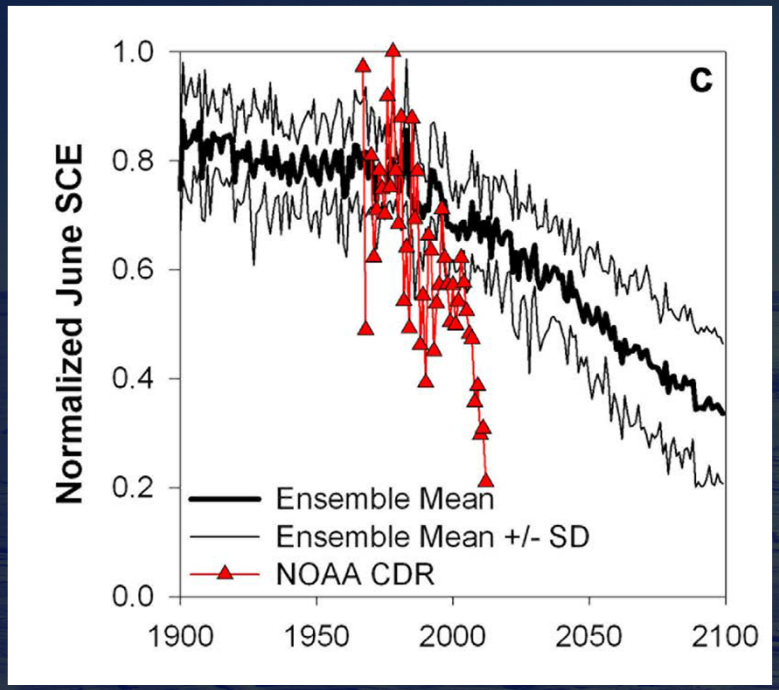


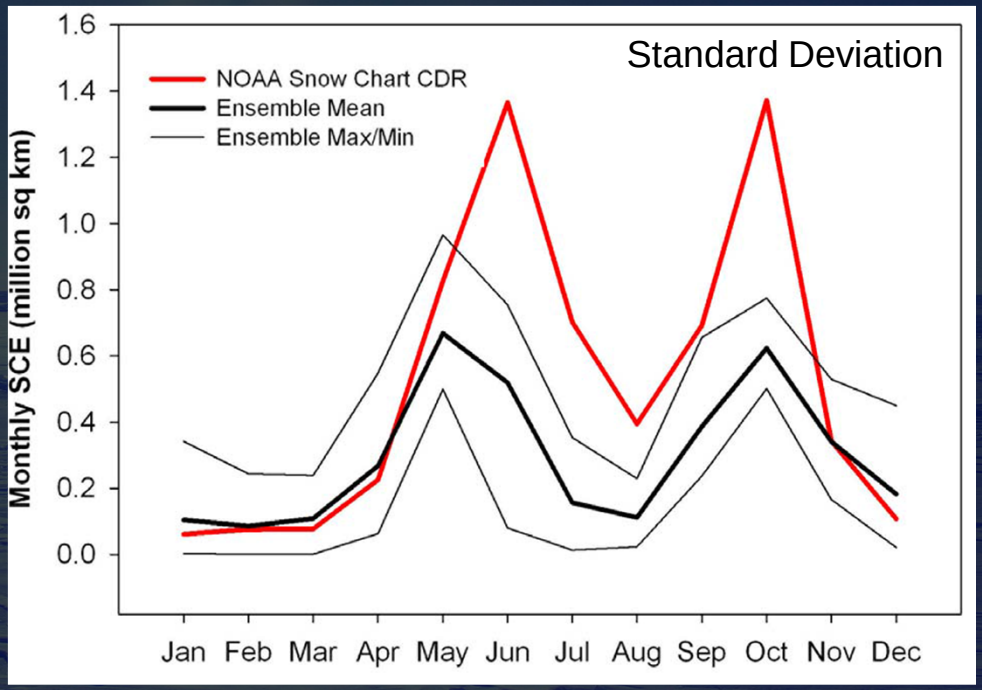
- ESA GlobSnow
  - 1979-2013 + NRT
  - Vis/IR (SE)
  - 1 km SE, 25 km SWE (PM, in situ)
- Rutgers/NOAA CDR/NASA MEaSUREs (SE)
  - Rutgers/NOAA
    - 1966-present SE (from NOAA IMS)
    - 100 km resolution, 24 km resolutoin
  - MEaSUREs
    - 1966-2012 SE (incl. MODIS [since 1999], PM, Rutgers)
    - Also Greenland surface melt (1987-2012), sea ice melt onset and sea ice age (1979-2012)
    - 25 km and 100 km resolution
- Passive microwave SE and SWE (thin and wet snow biases)
  - PM series and AMSR-E/AMSR2 (25 km)

http://www.globsnow.info; /http://climate.rutgers.edu/snowcover/

Snow cover obs vs models

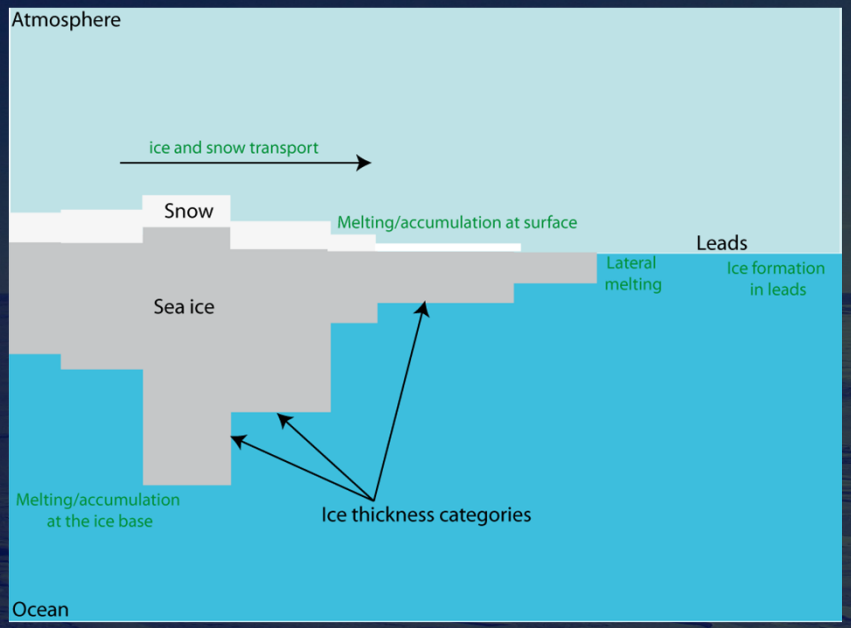
Comparison with CMIP5 RCP8.5





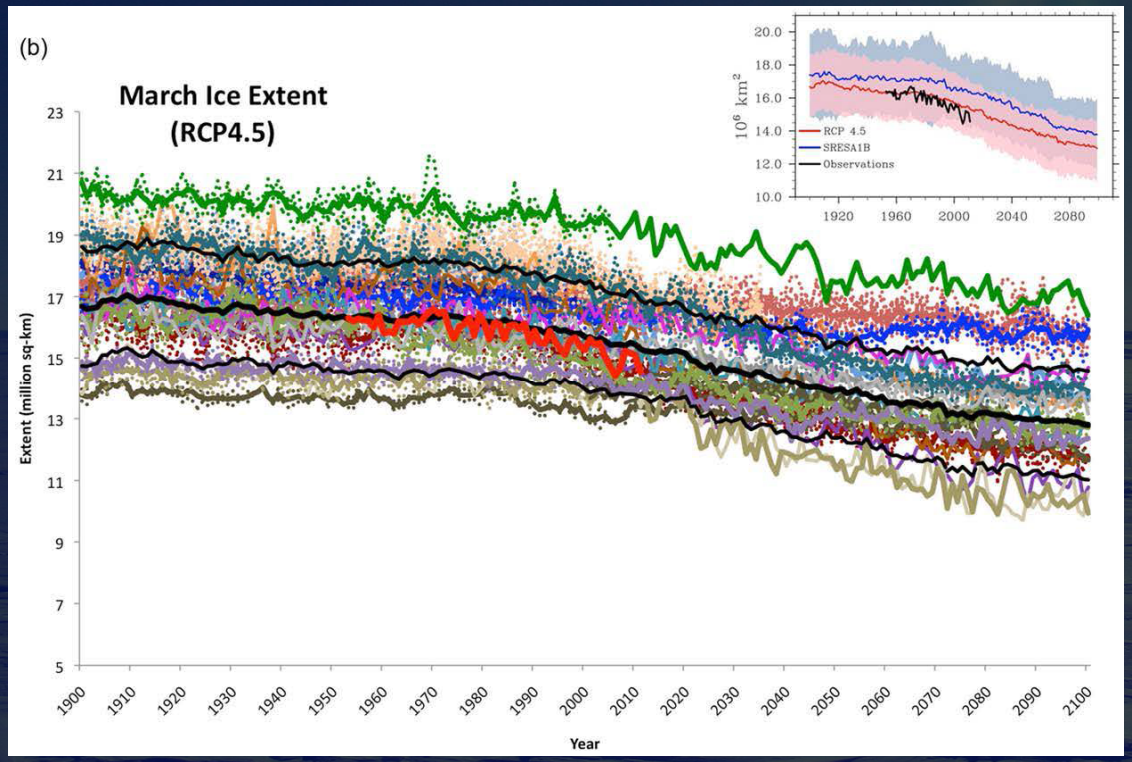
Derksen and Brown, GRL, 2012

Sea ice parameters of note



- Concentration/extent
- Drift/motion
- Thickness
- Type/age
- Melt onset, freeze-up
- Snow depth
- Deformation (leads, ridging)
- Albedo/temperature

Sea ice extent model-obs comparison



Large spread in historical extents in CMIP5 simulations

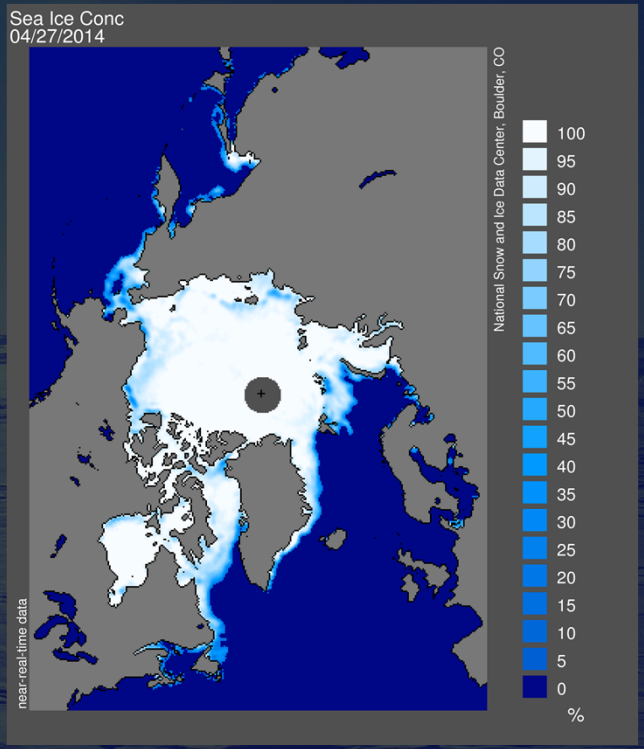
CMIP5 closer agreement to observations than CMIP3, due mainly to downward adjustment of mean

CMIP trends underestimated compared to observations

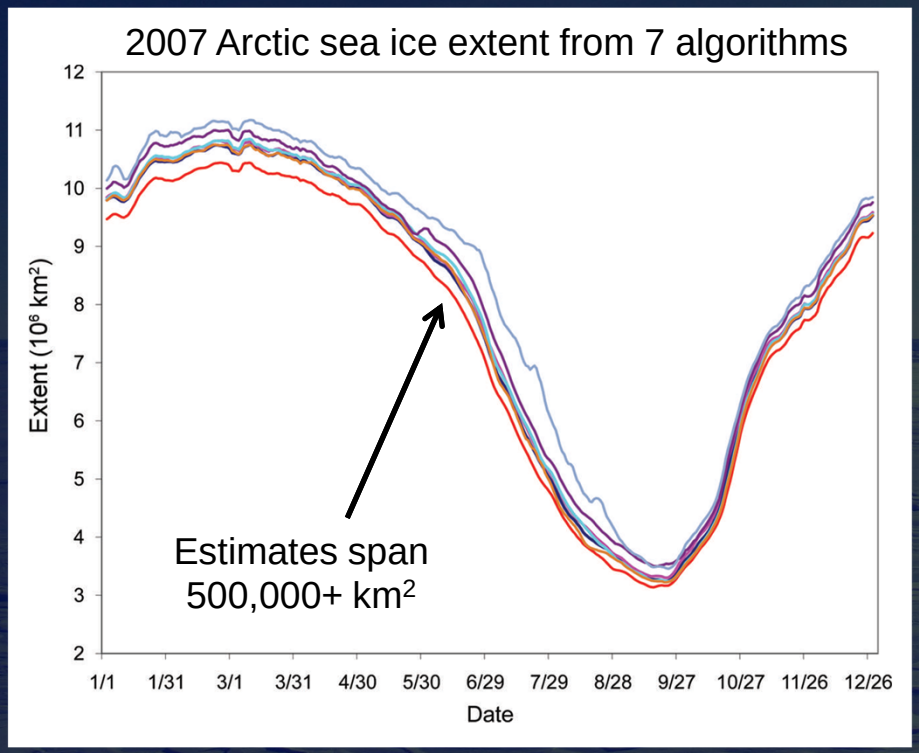
Stroeve et al., GRL, 2012

Sea ice concentration/extent

- Passive microwave (PM)
- 1979 – present (some products include only part of this period)
- Extended records back to the 1950s,
  - less complete, higher uncertainties
  - Use ice charts, reconnaissance data, and early pre-PM satellite records
- Low spatial resolution (12.5 – 25 km)
- Biases in melt, thin ice conditions
- Weather and coastal effects – mostly removed via automated filters
- Quantitative uncertainty estimates have been limited at best



Where is the sea ice edge?



- 15% contour is a standard definition of ice edge in PM data
  - Based on limited validation studies
  - Agreed with actual (0%) ice edge
- Actual agreement depends on ice conditions and algorithm sensitivity
- Low spatial resolution issue
  - One 25 km grid cell average difference in ice edge location can result in several hundred thousand km^2 difference in extent estimates

Kattsov et al., “Arctic sea ice: A grand challenge of climate science”, *J. Glaciology*, 2010.

Sea ice concentration products

Product	Source	Sensors	Time period	Spatial resolution	Uncertainty estimates	Format
NASA Team	NASA/NSIDC	PM series	1978-2012 + NRT	25 km	No	Binary
Bootstrap	NASA/NSIDC	PM series	1978-2012	25	No	Binary
NOAA	NSIDC/NOAA	PM series	1978-2011	25	Empirical	NetCDF4
OSI-SAF	EUMETSAT	PM series	1978-2009 + NRT	25	Empirical	NetCDF
ESA CCI[#]	ESA CCI	PM series	1978-2008	25	?	?
NT2/Bootstrap	NASA/NSIDC	AMSR-E	2002-2012	12.5	No	HDF4
ASI	Bremen	AMSR-E, AMSR2	2002-2012, 2013-present	6.25	No	HDF
Bootstrap	JAXA	AMSR-E, AMSR2	2002-2012, 2013-present	12.5	No	HDF
Hadley	Hadley Centre	Charts, OSI-SAF PM, other	1953-2007*	~100	No	ASCII, NetCDF

In progress for obs4MIPs

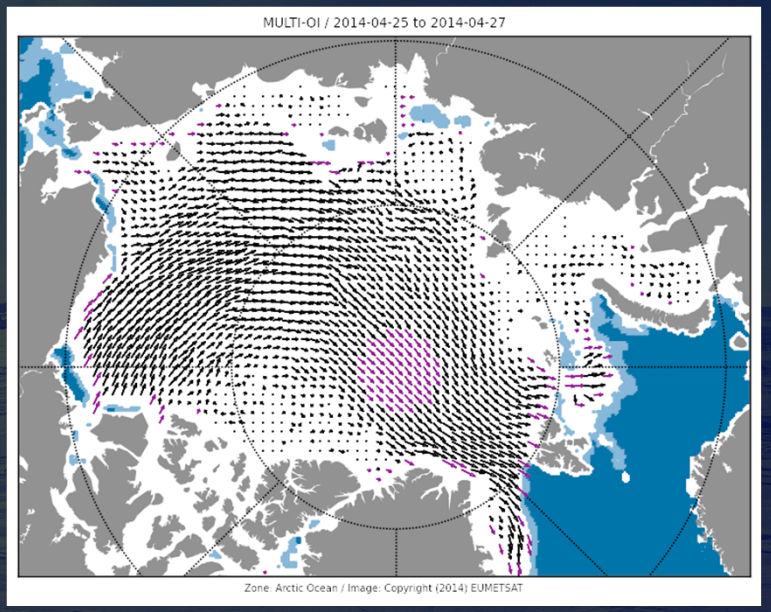
PM series = SMMR (1978-1987), SSM/I (1987-2007), SSMIS (2003-present)

[#]ESA CCI not yet released

*Hadley updating to Version 2 soon (Titchner and Rayner, JGR-Atm., 2014)

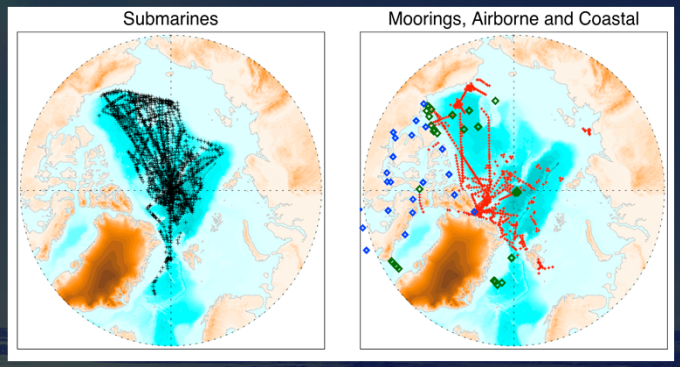
Sea ice drift

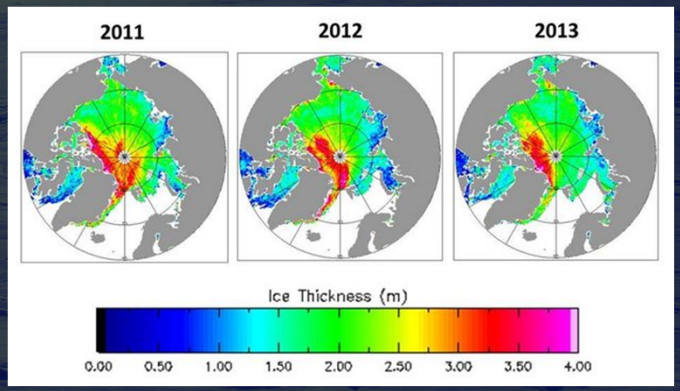
- Cross-correlation image feature matching methods
  - Summer melt issues
  - Less accurate in Antarctic
- Products
  - NSIDC Fowler et al., 1978-2012
    - Passive microwave and vis/IR
    - Buoy location
    - Wind forcing during summer
  - OSI-SAF PM and AVHRR, 2006-present (including NRT)
    - Passive microwave
    - Vis/IR
  - GlobIce, 2004-2011



Sea ice thickness

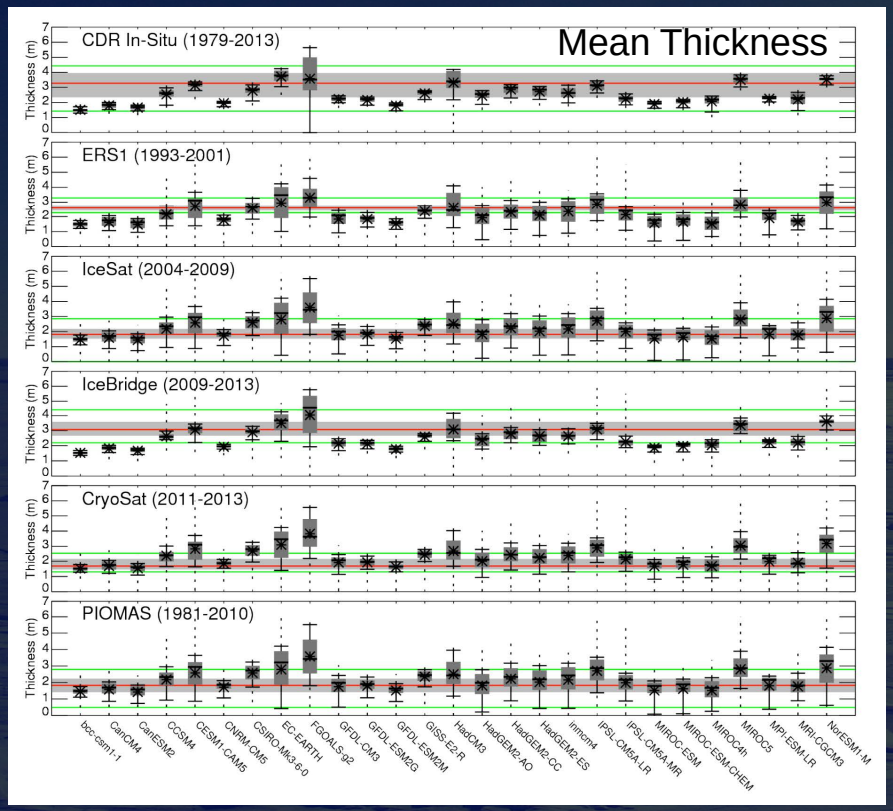
- Non-satellite (limited spatial and temporal coverage)
  - Submarine transects (1950s-1990s)
  - In situ
  - EM
  - Compiled by R. Lindsay, Univ. Wash.
- ESA
  - CCI ERS-1/2, Envisat
  - CryoSat-2
- NASA
  - ICESat
  - IceBridge
- Satellite data sets have large uncertainties, require further validation

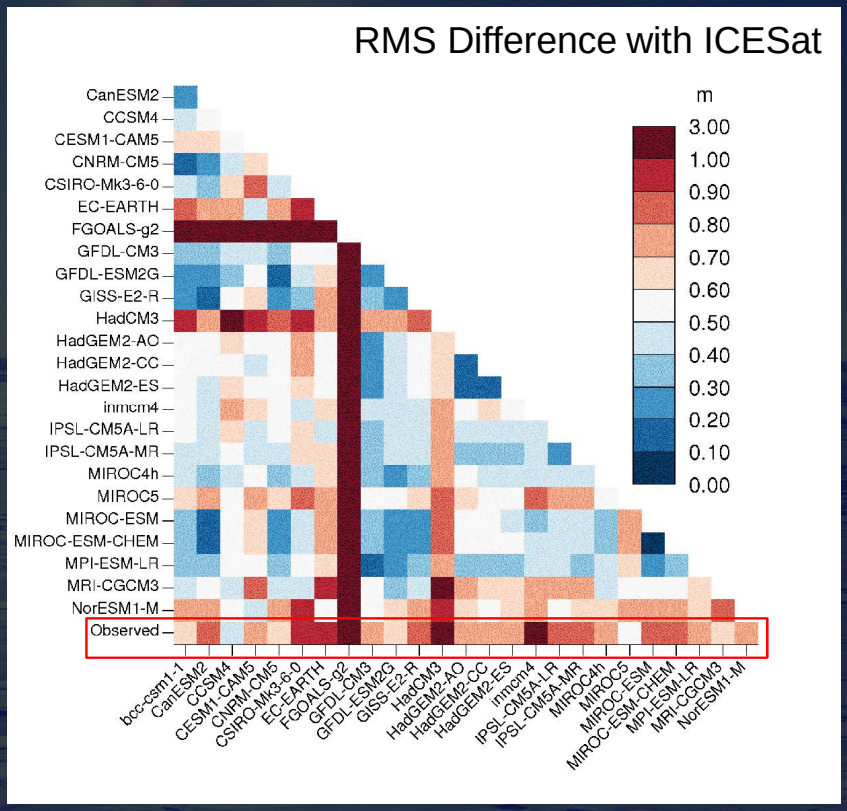




Top: Lindsay thickness CDR source data info; Bottom: CryoSat-2 ice thickness

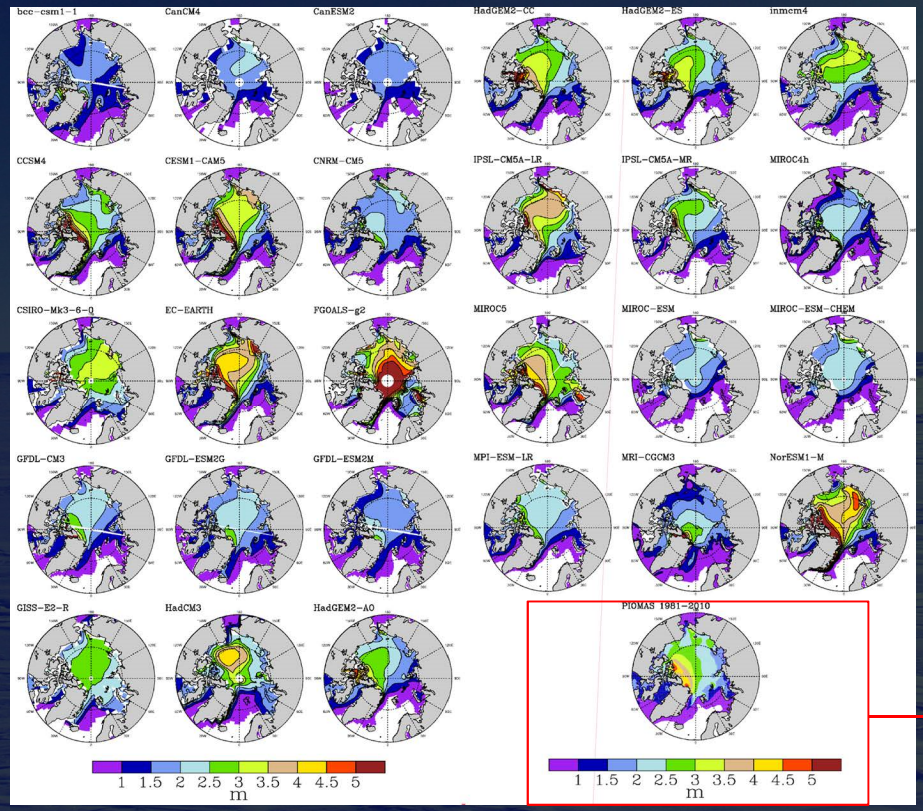
Thickness models vs. obs





Stroeve et al., *The Cryosphere Discussions*, 2014

Thickness models vs. obs



Thickness distribution is at least as important as mean thickness

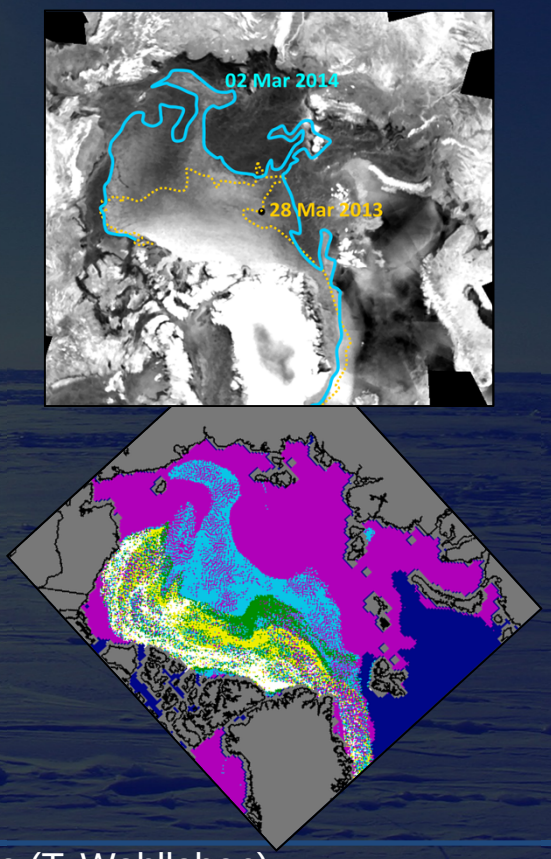
Representative model thickness distributions requires realistic SLP/wind patterns (along with ocean circulation and ice physics)

PIOMAS coupled ice-ocean model with concentration assimilation
(J. Zhang, Univ. Washington)

Stroeve et al., *The Cryosphere Discussions*, 2014

Sea ice type/age

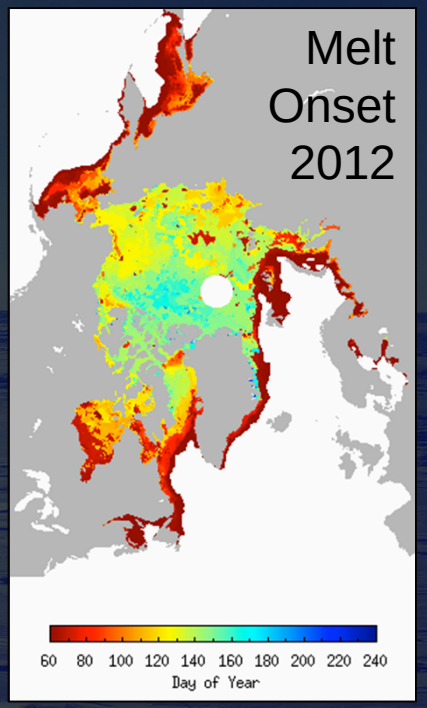
- Proxy for thickness
  - older ice ≈ thicker ice
- Longer, more complete record than thickness
  - Emissive/backscatter properties (multiyear, first-year)
    - EUMETSAT OSI-SAF (2005-present)
    - BYU QuikScat (2002-2009)
  - Lagrangian tracking (age in years)
    - Univ. Colorado (1978-2011 from NASA MEaSUREs, NRT available on demand)



Top: ASCAT multi-year ice from Canadian Ice Service (T. Wohlleben)
Bottom: Sea ice age by Lagrangian tracking, Univ. Colorado (M. Tschudi)

Other sea ice products

- Melt onset, freeze-up
  - PM, scatterometer
- Snow depth
  - Many difficulties, products not mature
  - PM over first-year ice
  - Altimetry (radar and laser)
- Ice surface temperature, albedo, melt ponds
  - MODIS, VIIRS, AVHRR
  - Resolution not sufficient to directly resolve individual melt ponds (need to parameterize)
  - No standard albedo products



Melt onset from NSIDC (M. Anderson et al., Univ. Nebraska)


Thanks!
Photo by Terry Haran, NSIDC